PB86-230091

Effects of Gridded Precipitation Bias on Wet Deposition Predictions

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Aug 86

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-230091

EPA/600/D-86/171
August 1986

EFFECTS OF GRIDDED PRECIPITATION BIAS ON WET DEPOSITION PREDICTIONS

T.L. Clark
R.L. Dennis
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina

D. Palka
Program Resources Incorporated
Research Triangle Park, North Carolina

M.P. Olson
E.C. Voldner
Atmospheric Environment Service
Downsview, Ontario

ATMOSPHERIC SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/D-86/171		PB86 230091/AS

4. TITLE AND SUBTITLE	5. REPORT DATE
EFFECTS OF GRIDDED PRECIPITATION BIAS ON WET DEPOSITION PREDICTIONS	August 1986
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Terry L. Clark; Robin L. Dennis; D. Palka; Marvin P. Olson and Eva C. Voldner	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Atmospheric Sciences Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, NC 27711	CCVN1A/01 - 3166 (FY-86)
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Atmospheric Sciences Research Laboratory - RTP, NC Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, N.C. 27711	14. SPONSORING AGENCY CODE EPA/600/09

15. SUPPLEMENTARY NOTES

16. ABSTRACT Spatially averaged precipitation amounts are used by many regional models to predict sulfur wet deposition amounts across the same grid cells. Just how well the grid prediction compares with the observation at a site within the grid cell will depend in part on how well the gridded precipitation amounts compare to the amounts at these sites. Gridded precipitation amounts routinely calculated by the CMC were compared to 1980 seasonal and annual precipitation amounts at 41 to 60 precipitation chemistry sites in eastern North America. For each period, the mean gridded amounts were found to be lower than the mean amounts at the sites, as much as 22.9%.

To assess the effects of this bias in the gridded precipitation amounts on the predictions of sulfur wet deposition amounts, 1980 weekly predictions of the Atmospheric Environment Service LRT Model at 18 eastern North American grid cells were recalculated using site precipitation amounts. As a result, the correlations between the predictions and observations increased by 0.1 to 0.2 for each season and the year. The match in the weekly observed and predicted temporal patterns improved by using site precipitation amounts.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	17
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

INTRODUCTION

Regional statistical, Lagrangian and Eulerian models have been developed and applied to predict monthly/seasonal/annual sulfur wet/dry deposition amounts across North America and Europe. Some statistical models predict the wet deposition amounts on the basis of statistical representations of the precipitation data irrespective of amount or rates (e.g., average durations of dry and wet periods and probabilities of the occurrence of precipitation). The remaining models require 3- to 24-hour precipitation amounts representing the model grid cells, which have areas ranging from 10^2 to 10^4 km^2. Based on the gridded precipitation amounts and the periods of occurrence, among many other variables, these latter models calculate both the pollutant mass depleted from the atmosphere between the sources and receptors and the mass scavenged across each model receptor cell.

These precipitation grids are created by averaging weighted precipitation amounts at every climatological precipitation measurement site within the confines of each grid cell. Consequently, the spatial variability of precipitation across subgrid scales is smoothed out. This consequence can be critical for model evaluations when a grid prediction is compared to an observation at a site within the grid cell.

Several questions therefore arise when predicting sulfur wet deposition amounts via regional models depending on gridded precipitation amounts. First, how well do seasonal and annual, spatially averaged precipitation amounts represent any point within the averaging domain? Second, what are the effects on the wet deposition predictions and model performance resulting from the smoothing of subgrid scale variability?

These questions are addressed by comparing, on a weekly basis, 1) grid cell precipitation amounts with amounts measured at precipitation chemistry sites within the grid cells and 2) model performance statistics based on unadjusted predictions with those based on predictions adjusted according to the differences between the grid and site precipitation amounts.

PRECIPITATION DATA

Gridded Data

Grids of 24-hour North American precipitation amounts are routinely processed and archived by the Canadian Meteorological Centre (CMC). These 127-km polar stereographic grids (Figure 1), which are 1/3 the size of the National Meteorological Center grids, are generated via analyses of 6-hour United States and Canadian climatic station precipitation amounts. For each grid cell, a precipitation amount is determined by arithematically averaging

1) the weighted mean by stations within 1.25 grid lengths of the grid point and

2) the weighted mean by quadrants of the cell (P_q), where

$$P_q = \frac{\sum_{j=1}^{4} w_j P_j}{\sum_{j=1}^{4} w_j}$$

and w_j is the average weight and P_j is the weighted average amount per quadrant j (1). Weights are assigned values on the basis to site distance from the grid point (Table I).

Site Data

Since 1980, episodic/weekly/monthly precipitation chemistry samples and precipitation amounts have been routinely measured at an increasing number of rural sites from six networks operating in the United States and Canada. These data are archived in the U. S. Environmental Protection Agency's Acid Deposition System (ADS), which is maintained by Pacific Northwest Laboratory (2).

The type of precipitation gauges and siting criteria used in both the United States and Canadian climatological and precipitation chemistry networks varies. Therefore, the collection efficiencies of the network gauges can vary significantly from one network to another, depending on meteorological conditions, e.g., wind speeds during precipitation events, frequency of snow events, etc. The consequences of these variations are not addressed here, however.

COMPARISON OF GRIDDED AND SITE PRECIPITATION AMOUNTS

Seasonal and annual precipitation amounts at each precipitation chemistry site east of 94° West longitude were computed for 1980 from the ADS data base. The winter season was defined to be January, February and March; spring was April, May and June; and so forth.

Sites were not considered in the seasonal comparisons if valid precipitation chemistry data were available for less than 80% of the season. Sites were not considered in the annual comparison if for any season valid precipitation chemistry data were available for less than 80% of the season. With few exceptions, precipitation amounts were available for the periods when precipitation chemistry data were unavailable.

These seasonal and annual amounts were compared in a pairwise fashion to the gridded seasonal and annual amounts for those 127-km cells containing the precipitation chemistry sites (Table II). The same gridded amount would be used more than once if there were more than one site within the same grid cell.

For every season and for the year, the mean gridded amount was 4.1 to 22.9% less than the mean site amount, indicating a bias in the gridded data set. The spring and summer seasons, when convective-type precipitation dominates, showed the lowest bias. On the other hand, the winter and autumn seasons, when frontal-type precipitation dominates, the bias increased markedly (from 4.1 and 6.9% for spring and summer, respectively, to 12.9 and 22.9% for winter and autumn, respectively). This is the reverse of what one would think.

Standard deviations of the seasonal and annual gridded amounts were 19 to 51% lower than those for the site amounts. The lower spatial variation exhibited in the gridded amounts is indicative of the averaging operation. Unlike the bias, no warm versus cold season pattern was apparent in the standard deviation differences.

The Pearson correlation coefficients resulting from the comparison of these two data sets are significantly different from zero at the 95% confidence level. (The 95% confidenece level is used hereafter). This means that these correlations were not likely realized by chance.

BIAS EFFECTS ON PREDICTIONS OF SULFUR WET DEPOSITION AMOUNTS

A bias toward lower values has been observed in the gridded precipitation amounts used as input to some regional sulfur deposition models. Since the wet deposition predictions are directly proportional to the gridded precipitation amounts in the model input data set, this bias would introduce a bias toward lower values in the sulfur wet deposition predictions.

This bias in the predictions is assessed for 1980 by adjusting the weekly sulfur wet depositions predicted for each grid cell by the Atmospheric Environment Service (AES) Lagrangian model, which routinely uses such precipitation grids (3). This year was selected since it was the only year when weekly model results were available. Adjustments were based on the ratio of site to gridded precipitation amounts. Both the unadjusted and adjusted predictions were compared to the observations at the precipitation chemistry sites. The difference in model performance would be attributed to the bias in the gridded amounts.

Prediction Adjustments

The AES model predicts both SO_2 and $SO_4^=$ wet depositions at each user-specified site at 3-hour time steps using the following algorithms:

$$SO_2 = \alpha_2 P_g [SO_2] \quad \text{and} \quad (1)$$

$$SO_4^{=} = \alpha_4 P_g^{0.6} [SO_4^{=}] \quad (2)$$

where scavenging ratios α_2 and α_4 are 3.0×10^4 and 1.0×10^6, respectively, P_g is the gridded precipitation rate (mm/day) and [ ] refers to the pollutant concentration.

The 3-hour deposition predictions from Equations 1 and 2 were summed for weekly periods for those grid cells containing the screened precipitation chemistry sites to form the unadjusted SO_2 and $SO_4^{=}$ samples. These predictions were then multiplied by

$$P_s'/P_g' \quad \text{for } SO_2 \quad \text{and}$$

$$[P_s'/P_g']^{0.6} \quad \text{for } SO_4^{=},$$

where P_s' and P_g' are the weekly site and gridded precipitation amounts (mm), respectively. The SO_2 and SO_4 wet depositions in both the unadjusted and adjusted samples are converted to S units and added to yield sulfur wet depositions.

Site Selection for the Comparisons

The 1980 precipitation chemistry data for eastern North American ADS sites were screened in the International Sulfur Deposition Model Evaluation to select "regionally representative" sites (sites with less than 10,000 tons/year of SO_2 emissions from sources within 50 km) with the highest seasonal and annual capture of valid data (4). From the screened data set, 18 episodic or weekly sites were selected (Figure 2). Two of these sites, U09 and U20, did not pass the highest level of screening criteria for autumn. Therefore, autumn and annual data were not used for these two sites.

Seasonal and annual sulfur wet deposition amounts were calculated for each of these sites according to the recommendations of the Unified Deposition Data Base Committee (5). Seasonal and annual precipitation amounts were calculated from standard gauge measurements as opposed to collector measurements.

Site Comparisons

Precipitation Data. Weekly time series of the site and gridded precipitation amounts (Figure 3) illustrate the tendency of the latter to be lower than the former, especially for those weeks when the site amounts were high. The occasional lags of one week could be a consequence of the slight discrepancies in the sampling periods of the climatic and precipitation chemistry networks.

Seasonal and annual precipitation correlations at each site (Table III) indicate that, in general, the trends are best matched for the winter and annual periods. Based on seasonal and annual rankings of the correlations at each site, the correlations are generally poorest for spring, summer and autumn. In addition, there was very little difference in the correlation rankings for these three seasons.

Wet Deposition Predictions. Based on the unadjusted predictions at the 18 sites, the model tended to overpredict annual observations by a factor of 1.25. The model predicted best in spring and summer, the highest deposition seasons, and overpredicted by a factor of 1.6 and 2.0 for autumn and winter, respectively (Table IV).

The net effect of the prediction adjustment was to slightly raise the mean prediction, thus increasing the model bias for all periods except spring. The most significant increase occurred for autumn (factor of 2.1) and annual (factor of 1.6). Except for autumn, the bias of the adjusted predictions was not significantly different from their counterparts.

On the other hand, the Pearson correlation coefficients showed improvements as a consequence of the prediction adjustments. For the unadjusted sample only the summer correlation of 0.56 was significantly different from zero, meaning that for the other seasons, the correlations could have been realized by chance. On the other hand, the adjusted sample correlations were significantly different from zero for all periods except autumn.

CONCLUSIONS

A comparison between 1980 gridded precipitation amounts and precipitation amounts at independent sites within these grid cells showed seasonal and annual biases toward lower values of the gridded amounts. The biases were pronounced in winter and autumn. Effects of these biases on the AES model predictions of seasonal and annual sulfur wet depositions at 18 sites in eastern North America were assessed. Weekly predictions were adjusted according to the differences in the weekly gridded and site precipitation amounts.

The results presented here, which should not be interpreted as an evaluation of the AES model, indicate that, in general, the seasonal and annual bias and the correlations between 16 to 18 pairs of 1980 predicted and observed sulfur wet depositions increased when the AES model predictions were adjusted to account for the bias in the gridded precipitation amounts. However, even with unadjusted precipitation amounts the model overpredicted.

Except for summer, correlations between observations and unadjusted predictions were not significantly different from zero at the 95% confidence level. However, except for autumn, correlations between observations and adjusted predictions were significantly different from zero. Therefore, as a consequence of the precipitation adjustment (i.e., substituting the precipitation amount at the site for the grid cell amount), the match between the temporal patterns of the observed and predicted sulfur wet deposition amounts improved, yet the existing difference in pattern level did not.

REFERENCES

1. D. Davies, "Three-layer numerical forecasts of precipitation amount", Canadian Meteorological Memoirs, No. 25, Canadian Meteorological Centre (1967).

2. C. R. Watson and A. R. Olsen, "Acid Deposition System (ADS) for statistical reporting: System design and user's code manual", U. S. Environmental Protection Agency, EPA/600/8-84-023 (September 1984).

3. National Research Council, Acid Deposition: Atmospheric Processes in Eastern North America", National Academy Press, Washington, D. C., 1983, pp. 60-62.

4. E. C. Voldner, A. Sirois and T. L. Clark, "Data screening and calculation procedures for the North American precipitation chemistry data to be used in the International Sulfur Deposition Model Evaluation", APCA/ASQC Specialty Conference on Quality Assurance in Air Pollution Measurements, Boulder, CO, October 1984.

5. Lusis, M. A., W. H. Chan, P. K. Misra, E. C. Voldner, R. J. Vet, A. R. Olsen, D. Bigelow and T. L. Clark, "A unified wet deposition data base for eastern North America - Data screening and calculation procedures and results", Paper 86-29.1, Annual APCA Meeting, Minneapolis, MN, June 1986.

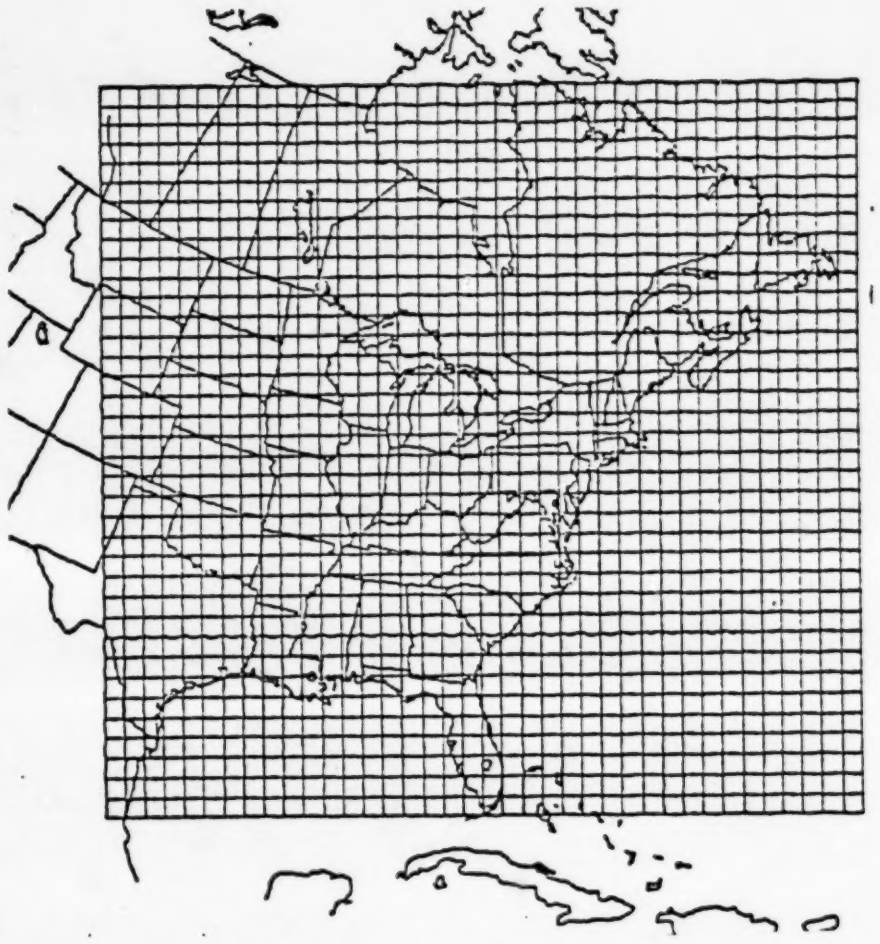


Figure 1. A portion of the Canadian Meteorological Centre precipitation grid configuration, with a resolution of 127 km at 60° North latitude, superimposed on a polar stereographic projection map.

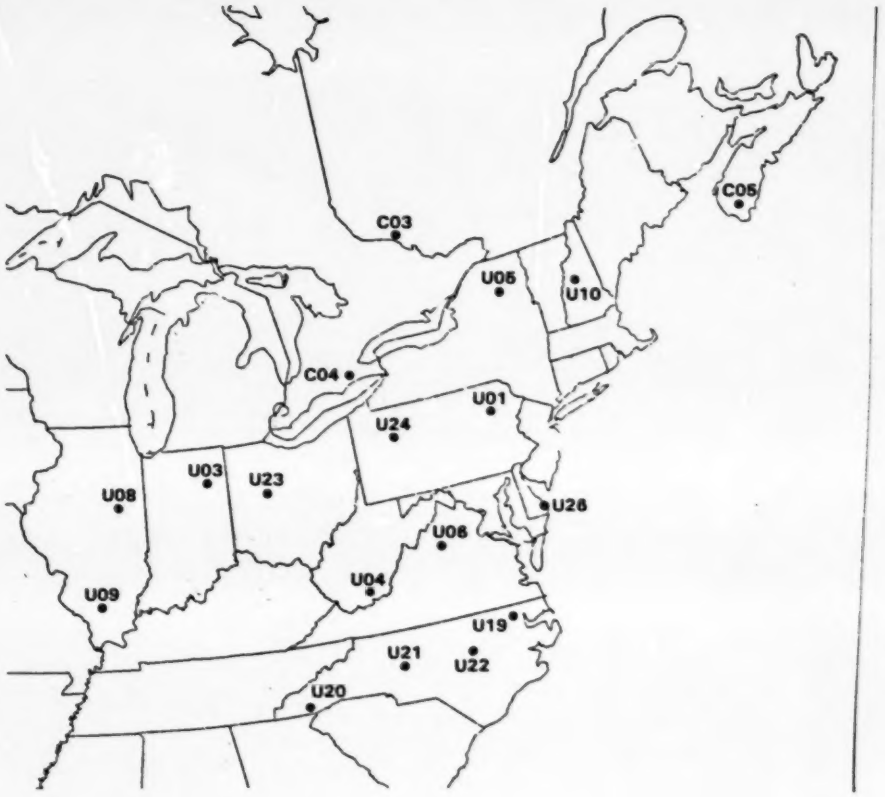


Figure 2. The 19 episodic or weekly precipitation chemistry sites at which unadjusted and adjusted AES model predictions of sulfur wet deposition were compared to observations.

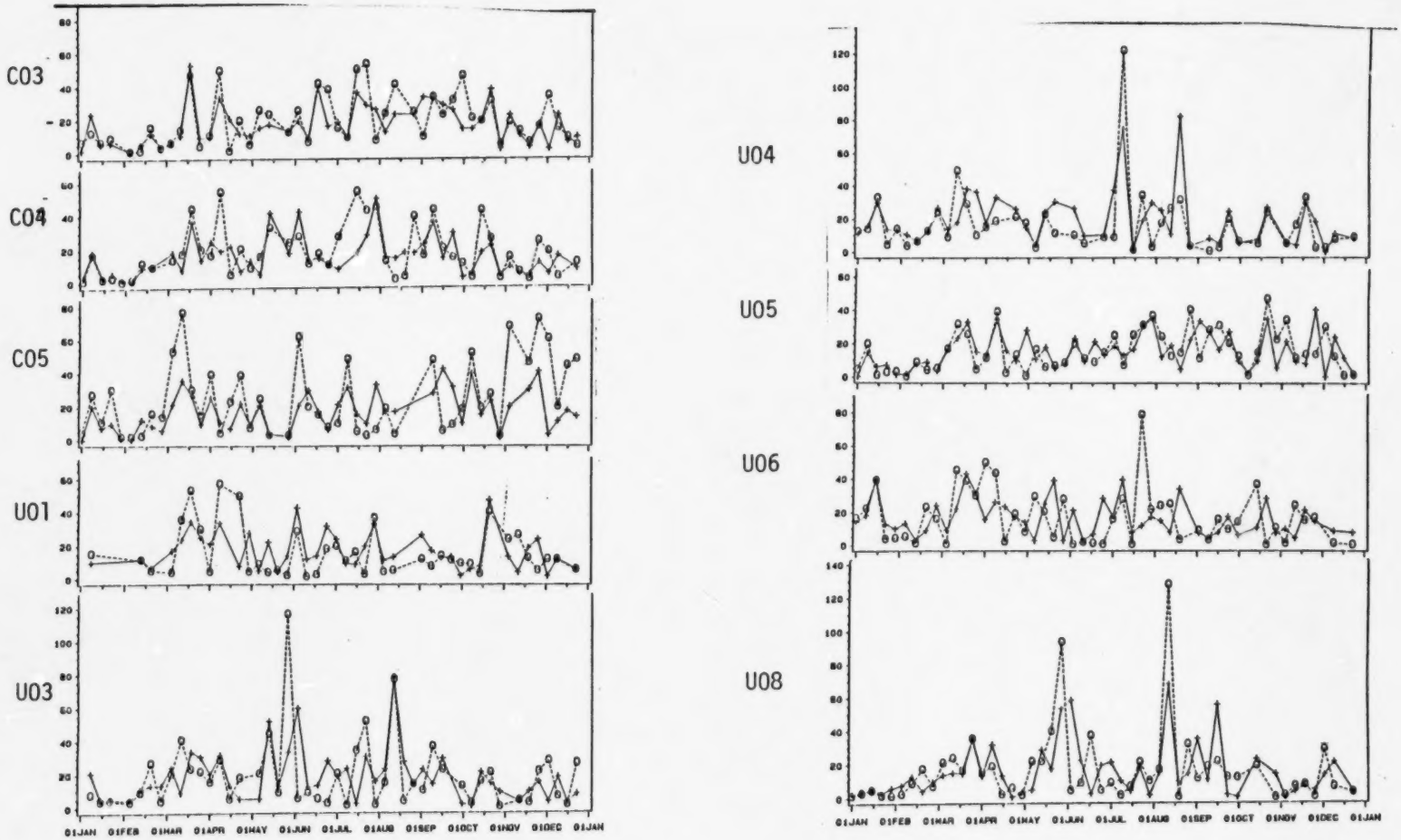
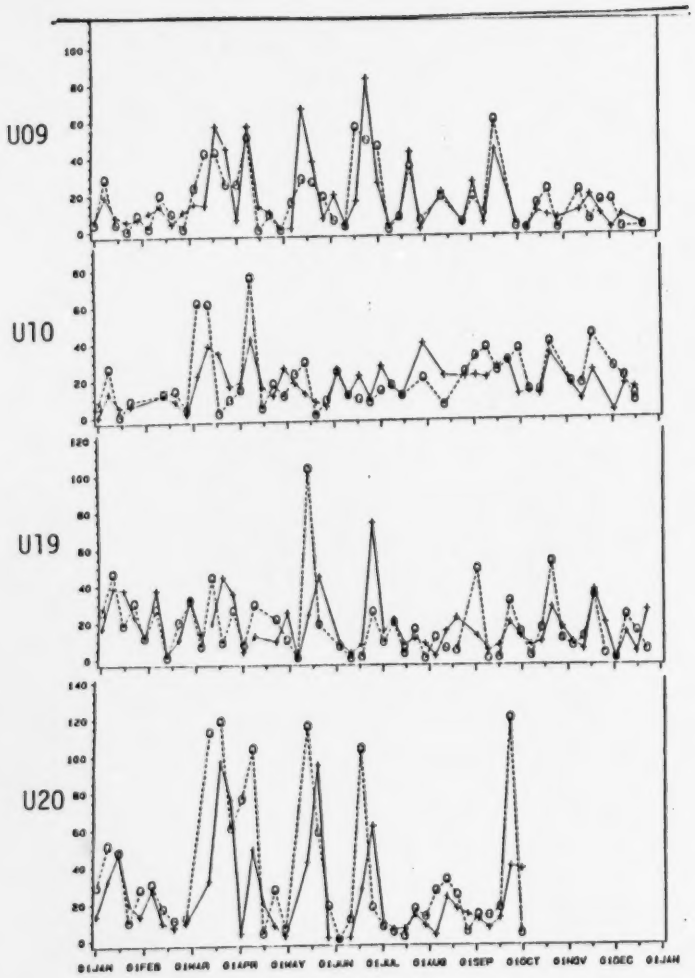


Figure 3. Time series of gridded (+) and site (o) weekly precipitation amounts (mm) for each of the 19 sites.



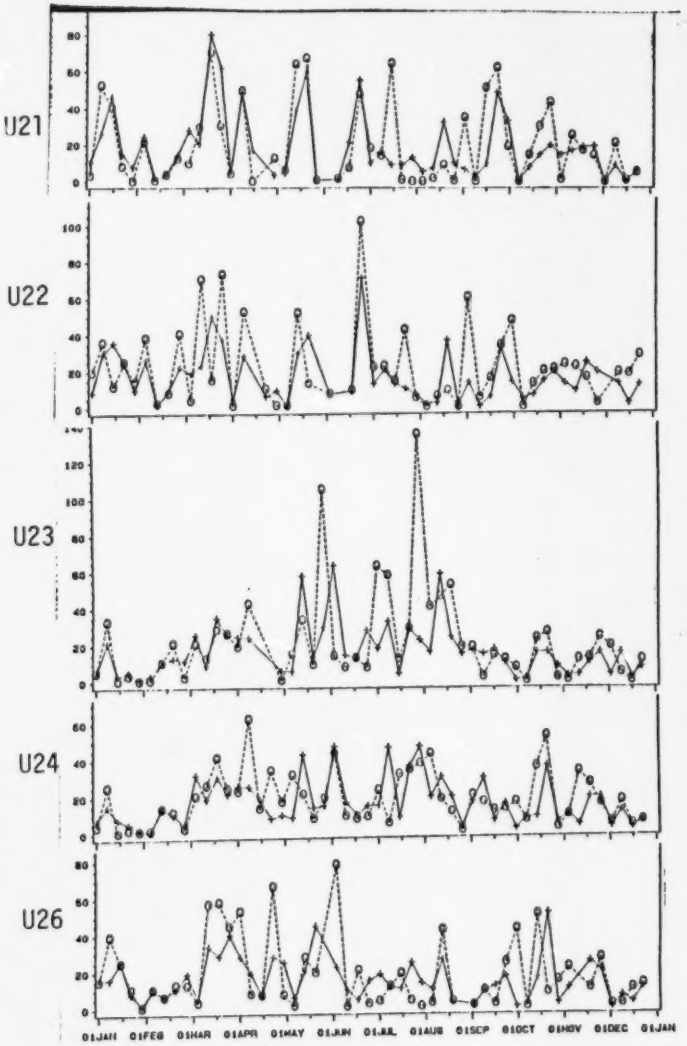


Figure 3. Continued.

Table I. Weights assigned to climatological stations in the CMC precipitation data gridding.

Distance from Grid Point (Units of Grid Length)	Weight
$\leq$ 0.30	1.0
0.30 - 1.00	linearly decreasing from 1.0 to 0.1
1.00 - 1.25	0.1

Table II. Statistical results of the comparison of gridded and site precipitation amounts (mm).

PERIOD	SAMPLE SIZE	SITE MEAN	SITE S.D.	GRID MEAN	GRID S.D.	BIAS (%)	RESID. S.D.	CORRELATION COEFFICIENT
WINTER	51	209	94	182	76	12.9	58	0.79
SPRING	60	247	77	230	52	6.9	57	0.67
SUMMER	58	268	101	257	60	4.1	68	0.76
AUTUMN	52	205	97	158	48	22.9	62	0.84
ANNUAL	41	947	187	825	102	12.9	155	0.56

Table III. Correlation of the site and gridded precipitation amounts at each of the 19 sites.

SITE	WINTER	SPRING	SUMMER	FALL	ANNUAL
C03	0.95	0.73	0.43	0.35	0.67
C04	0.94	0.37	0.44	0.65	0.63
C05	0.88	0.66	0.25	0.55	0.51
U01	0.91	0.33	0.62	0.61	0.51
U03	0.38	0.28	0.64	0.23	0.46
U04	0.46	0.65	0.68	0.76	0.67
U05	0.85	0.44	0.35	0.42	0.56
U06	0.79	-0.14	0.02	-0.21	0.20
U08	0.86	0.39	0.73	0.41	0.64
U09	0.69	0.64	0.89		0.70b
U10	0.58	0.77	0.19	0.51	0.56
U19	0.39	0.27	0.32	0.59	0.39
U20	0.76	0.41	0.87		0.59b
U21	0.83	0.91	0.40	0.60	0.71
U22	0.36	0.89	0.35	0.10	0.62
U23	0.88	0.24	0.32	0.63	0.44
U24	0.88	0.39	0.25	0.68	0.51
U26	0.87	0.42	0.52	0.00	0.46

(b) The fall season's validation data did not meet the criteria. Obviously, annual also did not meet the criteria but for this site, the value under annual is a correlation using the data from the other 3 valid seasons.

Table IV. Comparison of 1980 unadjusted (UNA) and adjusted (ADJ) sulfur wet deposition predictions with observations (OBS) (kg S/ha).

PERIOD		MEAN	S.D.	BIAS	S.D.	CORRELATION COEFFICIENT
WINTER	N=18					
	OBS	1.4	0.6			
	UNA	2.7	1.4	-1.3	1.3	0.35
	ADJ	2.8	1.4	-1.4	1.3	0.45
SPRING	N=18					
	OBS	2.5	1.0			
	UNA	2.1	0.8	0.4	1.0	0.43
	ADJ	2.3	0.9	0.2	0.8	0.65
SUMMER	N=18					
	OBS	2.9	1.5			
	UNA	3.1	1.0	-0.2	1.3	0.56
	ADJ	3.4	1.3	-0.5	1.0	0.78
AUTUMN	N=16					
	OBS	1.2	0.5			
	UNA	1.9	0.7	-0.7	0.8	0.05
	ADJ	2.6	1.0	-1.5	1.0	0.24
ANNUAL	N=16					
	OBS	7.8	2.8			
	UNA	9.8	3.4	-2.0	3.7	0.31
	ADJ	10.9	3.5	-3.1	3.2	0.50